The 3rd Annual GOCI Validation Campaign: Preliminary Cruise Report

Chief Scientist: J. K. Choi (KOSC)
KOSC Contact: Young-je Park (KOSC)
Vessel: *R/V Eardo*
Study area: Southern Yellow Sea/East China Sea
NASA Principal Investigator: Antonio Mannino (NASA/GSFC)
NASA FSG Participants: Joaquin Chaves, Scott Freeman, Aimee Neeley (SSAI)

The Ocean Ecology Laboratory's Field Support Group (FSG) participated in the 3rd Annual GOCI Validation Campaign organized by the Korean Ocean Satellite Center (KOSC), a branch of the Korean Institute of Ocean Science and Technology (KIOST). The annual validation campaign is part of the calibration and validation program KOSC maintains in support of the Geostationary Ocean Color Imager (GOCI) sensor onboard the Korean-operated COMS satellite. Launched in June 2010, GOCI is the first geostationary ocean color mission; it acquires data in 8 spectral bands (6 visible, 2 NIR) with a spatial resolution of approximately 500 m. GOCI acquires 8 full daytime images from 9 am to 4 pm local time of the waters centered around the Korean Peninsula. The ocean data products that can be derived from the imagery acquired are mainly surface chlorophyll *a*, optical diffuse attenuation coefficient, chromophoric dissolved organic matter (CDOM) and suspended particles concentrations.

Given NASA's collaboration with KOSC and ongoing development of its own geostationary ocean color mission (GEO-CAPE) the FSG was invited to participate on this iteration of the annual field validation campaign. The field deployment was planned as an ocean-going research cruise aboard KIOST's 45m *R/V Eardo*, and planned to target sampling stations in the Yellow and East China Seas. In addition to the Korean and NASA teams, three scientists from *Laboratoire d'Océanographie de Villefranche* (LOV) completed the 16-person scientific party.

The objectives laid out by the organizers of the 3rd annual GOCI validation field campaign were:

1. Acquisition of field data for GOCI validation at regular and 8-hour stationary stations
2. Field data acquisition for GOCI atmospheric correction algorithm
3. Field investigation of southern Yellow Sea region for GOCI applications
4. Field investigation of East China Sea for GOCI applications

NASA/FSG Science Objectives

The GOCI Validation campaign presented a valuable opportunity to collect in-water optical measurements concurrently with phytoplankton pigments and other biogeochemical parameters to support NASA's satellite ocean color validation activities at GSFC. In addition, this campaign offered the opportunity to accrue valuable experience conducting and analyzing validation measurements in the context of a sampling plan designed to specifically support a geostationary ocean color mission (i.e., GOCI).

Phytoplankton pigments, biogeochemical measurements

Near-surface samples (~2 m) were collected for HPLC analysis of phytoplankton pigments, particulate organic carbon (POC), dissolved organic carbon (DOC), total suspended matter (TSM), and spectral phytoplankton and CDOM absorption (a_φ, a_g). For these parameters, samples were collected with a peristaltic pump outfitted with an acid-clean silicon hose deployed over the side while on station. All filtration and cold sample preservation for these parameters were conducted on board. Samples were subsequently transported to NASA-GSFC for further analyses. In addition to the CDOM samples processed and stored for on shore determination, a_g was also measured on board on all samples shortly after collection on an UltraPath liquid waveguide system.

In-water Optical Measurements (AOPs, IOPs)

The FSG package to measure inherent optical properties (IOPs) consisted of 2 ac-s (one with a 0.2 um filter to measure a_g), a bb-9, a VSF-9, and a CTD. The ac-s measures absorption and attenuation (and total scattering by difference) at ~ 80 wavelengths between 400 and 740 nm, while the bb-9 measures backscatter at 9 wavelengths and 117°. The VSF-9 measures scattering at 9 angles from 60° to 170° at 532 nm. The KOSC package, which was deployed attached to the NASA/FSG one, contained an ac-s and an HS-6, but no CTD. The HS-6 (HOBI Labs) measures backscatter at 6 wavelengths. The IOP packages profiled to within 10 meters of the seafloor, reaching up to 100 m in depth, collecting data autonomously for later download. Nine stations were profiled with the IOP system, while stations D10 and D12 were sampled three times each during daylight hours (Table **2**).

Apparent optical properties (AOPs), and both downwelling irradiance (E_d) and upwelling radiance (L_u), were measured at six stations using a Biospherical Instruments C-OPS system. Incoming solar irradiance (E_s) was measured with a matching reference radiometer. At one of these stations, and one other time when we were unable to deploy the C-OPS system, the sky was clear enough to use a Microtops Sun Photometer, on loan from Alexander Smirnov at GSFC, who will incorporate the data into the AERONET database.

Other measurements

For discrete depth sampling, the *Eardo* was equipped with a conductivity, temperature, depth (CTD) instrument, equipped with a chlorophyll fluorometer and a photosynthetically available radiation (PAR) sensor. These were attached to a 22 10L-bottle rosette operated by the Korean team. Korean scientists also deployed a Satlantic Fluorescence Induction and Relaxation System (FIRe) set up to collect underway measurements during the length of the cruise.

Campaign Narrative and Preliminary Results

FSG staff arrived at KIOST HQs in Ansan, South Korea, on September 21, 2013, where cruise participants met to discuss the cruise plan, sampling logistics, and objectives. On September 24th, the science party travelled to the KIOST Nam-he Research Center in Jangmok, Geoje Island, for cruise mobilization. Set up commenced the morning of September 25th, and the cruise got

underway at noon local time on the same day.

Weather conditions considerably reduced the number of days at sea in which the *R/V Eardo* could operate safely, and in two separate occasions, family emergencies on shore required the cruise to be diverted back to Jeju Island to drop off science and crew personnel. We were able to conduct measurements in 9 out of the 43 sampling stations originally planned (Figure **1**).
At the beginning of the campaign on 9/25, instead of heading out to sea immediately, the ship maneuvered between islands on the southwest coast to harbor in Wan-do. We stayed in port on 9/26 and resumed work the next day. Because weather conditions were still not favorable offshore, an *ad hoc* transect ('F' line; Figure **1**) closer to shore was added to the cruise plan. On 9/29, rain curtailed our use of the C-OPS system, as rain on the reference sensor leads to errors in E_s measurement. On 9/30, we again experienced high wind and seas. The ship took shelter close to Jeju Island. Stations D10 and D12 were sampled three times each on 10/1 and 10/2, respectively, from approximately 9 to 5 pm local time. However, on 10/2 heavy rain limited the AOP work. Finally, the campaign ended more than a day early because of the risk of typhoon Fitow heading into the survey area, so the ship diverted to Geoje Island.

A total of 149 sample replicates were collected during the campaign for all biogeochemical parameters: HPLC pigments, particulate absorption (a_p), POC, CDOM (a_g), DOC, and SPM (Table **1**). Radiometry deployments were conducted at six stations (Table **2**). For all stations, surface samples for each parameter were collected using a peristaltic pump equipped with clean silicon tubing (~2m) in conjunction with the IOP profiles. At station D10, water was collected at the chlorophyll maximum, at 38m, from the CTD rosette, in addition to the aforementioned surface sampling.

On Board CDOM work

CDOM absorption scans were performed on board on all samples (n = 14) collected during the campaign shortly after collection (Table **3**). The scans were performed on an UltraPath liquid waveguide system using a 2 m pathlength. Samples were filtered through 47 mm GFF filters and were allowed to equilibrate to room temperature. After each scan, the temperature of the sample and the deionized water used as reference were measured, and in all cases the temperature difference between those were < 0.5 °C. A salinity correction devised in advance for the waveguide system used on board was used to correct the absorbance spectra measured against a deionized water reference. The salinity correction accounts for the difference in refraction indices between the sample and the reference.

Preliminary results from the work performed on board showed that surface CDOM absorption coefficients (a_g) in the study region during this campaign were strongly associated with surface salinity (Figure **2**a, b). Higher values of a_g at 400nm occurred at the southwestern end of the sampled region, the area with the lowest surface salinities. These preliminary findings suggest that drainage from the Yangtze River, just to the west of the area of study (not shown), may have a strong influence in the optical properties.

Tables and Figures

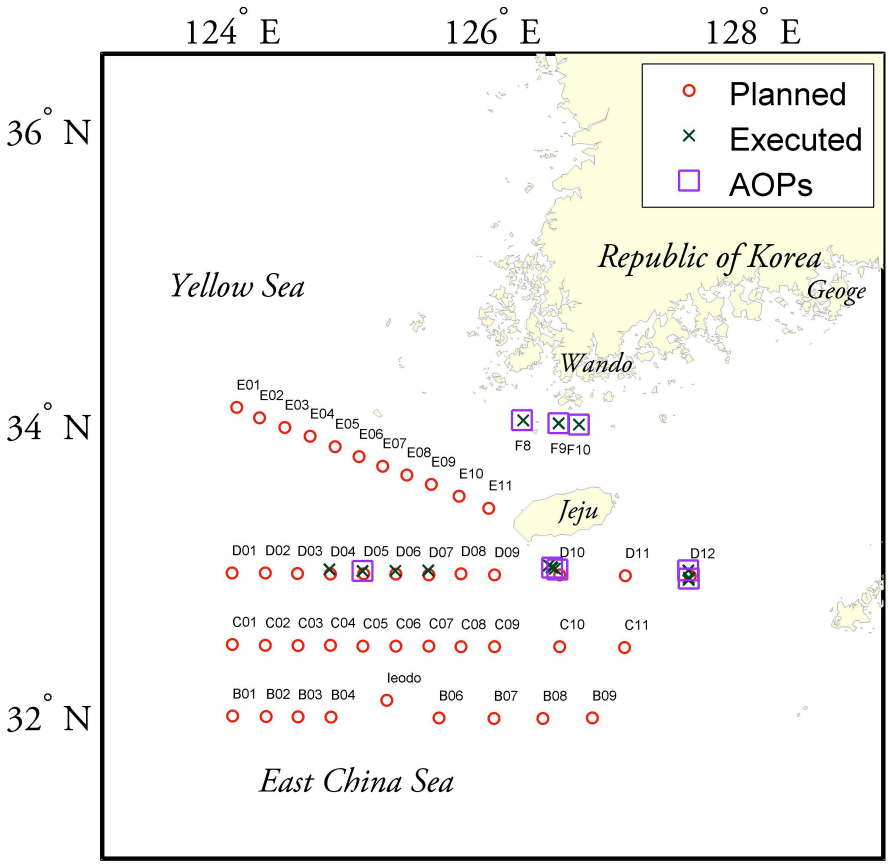

Figure 1. Area of study of the 3rd Annual GOCI Validation Campaign. Planned and executed stations. Squares denote stations where AOP measurements where conducted.

Table 1. Biogeochemical parameters collected on the 3rd Annual GOCI cruise.

Parameter	Number of samples collected
HPLC Pigments	28
a_p	28
POC	28
a_g	13
DOC	28
SPM	24
Total	149

Table 2. Stations occupied, environmental conditions encountered. Local time is UTC + 9. Several stations had conditions unfavorable for AOP measurement (rain or low sun angle). These are indicated with 'no' in the AOPs column.

Date	UTC (IOPs)	Station	Latitude	Longitude	Depth, m	Percent Clouds	Wind speed, m/s	AOPs
09-27	1:25	F10	33.99379	126.6609	58	70	6.5	yes
09-27	4:34	F09	34.00168	126.5044	42	60	7	yes
09-27	7:37	F08	34.02331	126.2233	53	80	8	yes
09-28	23:54	D07	32.99381	125.5037	98	100	5	no
09-29	2:45	D06	32.99146	125.2509	90	100	1.7	no
09-29	5:37	D05	32.99012	124.9984	83	100	1.8	yes
09-29	9:16	D04	33.00179	124.7446	77	100	3	no
10-01	3:47	D10	32.99989	126.4964	110	50	5.3	yes
10-01	5:56	D10	33.01303	126.4556	110	80	9.4	yes
10-01	8:02	D10	33.01303	126.4556	110	40	6.7	yes
10-02	1:22	D12	32.99385	127.5016	138	100	9	yes
10-02	3:54	D12	32.93828	127.506	135	90	10	yes
10-02	6:31	D12	32.93828	127.506	136	50	8	yes

Table 3. CDOM absorption scans conducted on board on an UltraPath liquid waveguide system during the 3rd Annual GOCI Validation Campaign

File	**Date**	**SDY**	**Time, UTC**	**Station**	**Depth, m**
1	20130927	270	1:33:00	F10	2
4	20130927	270	1:33:00	F10	2
2	20130927	270	4:40:00	F9	2
3	20130927	270	4:40:00	F9	2
5	20130927	270	7:35:00	F8	2
6	20130927	270	7:35:00	F8	2
7	20130928	271	23:56:00	D7	2
8	20130928	271	23:56:00	D7	2
9	20130929	272	2:49:00	D6	2
10	20130929	272	2:49:00	D6	2
11	20130929	272	5:32:00	D5	2
12	20130929	272	5:32:00	D5	2
13	20130929	272	9:14:00	D4	2
14	20130929	272	9:14:00	D4	2
15	20131001	274	3:47:00	D10	2
16	20131001	274	3:47:00	D10	2
17	20131001	274	3:47:00	D10	2
18	20131001	274	6:01:00	D10	2
19	20131001	274	6:01:00	D10	2
20	20131001	274	6:45:00	D10	38

Table 3 (cont.). CDOM absorption scans conducted on board on an UltraPath liquid waveguide system during the 3rd Annual GOCI Validation Campaign					
21	20131001	274	6:45:00	D10	38
22	20131001	274	8:04:00	D10	2
23	20131001	274	8:04:00	D10	2
24	20131002	275	1:12:00	D12	2
25	20131002	275	1:12:00	D12	2
26	20131002	275	1:12:00	D12	2
27	20131002	275	3:47:00	D12	2
28	20131002	275	3:47:00	D12	2
29	20131002	275	6:29:00	D12	2
30	20131003	276	6:29:00	D12	2
31	20131004	277	6:29:00	D12	2

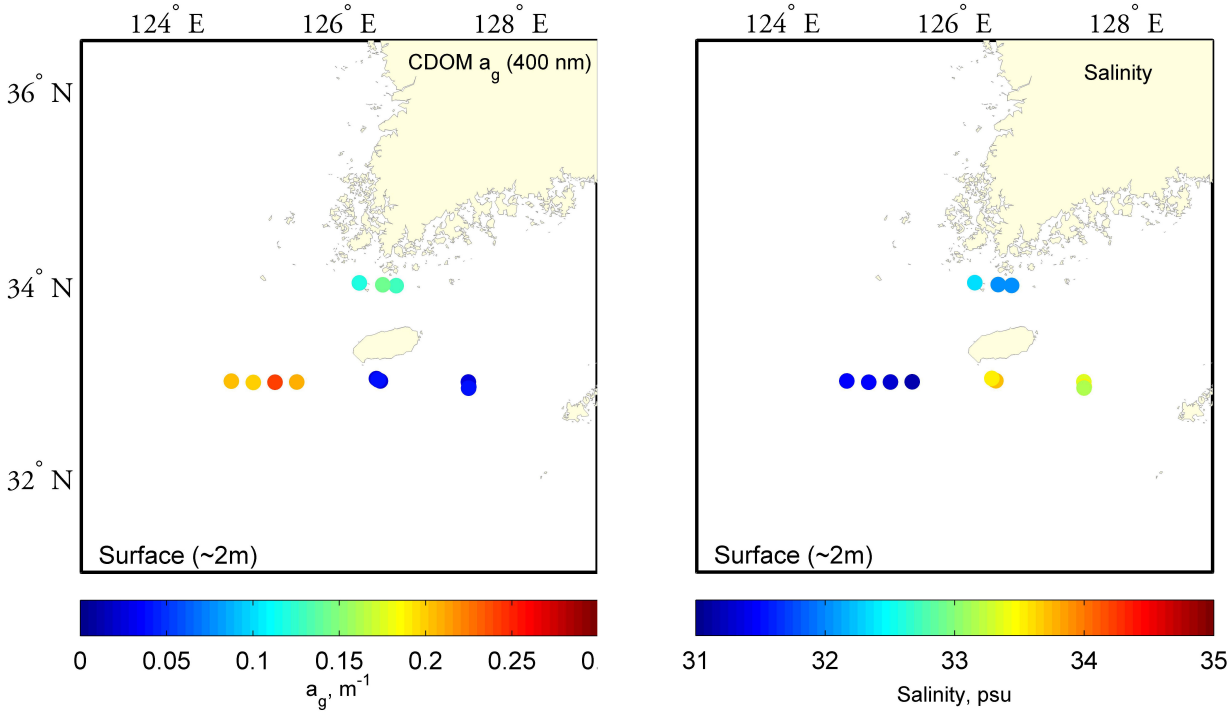

Figure 2. a. Spectral absorption coefficient of CDOM (a_g) at 400 nm from near surface samples (~2m depth), and b. near surface salinity for samples collected during the 3rd annual GOCI validation campaign.

Figure 3. Clockwise from the top: *R/V Eardo* at the Geoge Is. KIOST facility prior to departure. Science party for the 3rd annual GOCI validation campaign. NASA/FSG cage containing various instrument for measuring inherent optical properties (IOPs). A. Neeley (NASA/SSAI) processing samples for pigments and other biogeochemical parameters during the GOCI campaign. J Chaves from NASA/SSAI deploying the C-OPS instrument for measuring apparent optical properties. Predominant atmospheric conditions during the GOCI campaign. S.Freeman (NASA/SSAI) calibrating IOP instrumentation prior to the start of the GOCI campaign. Center: S. Freeman supervises the deployment of the IOP instrumentation.

Appendix: Preliminary CDOM data processing.

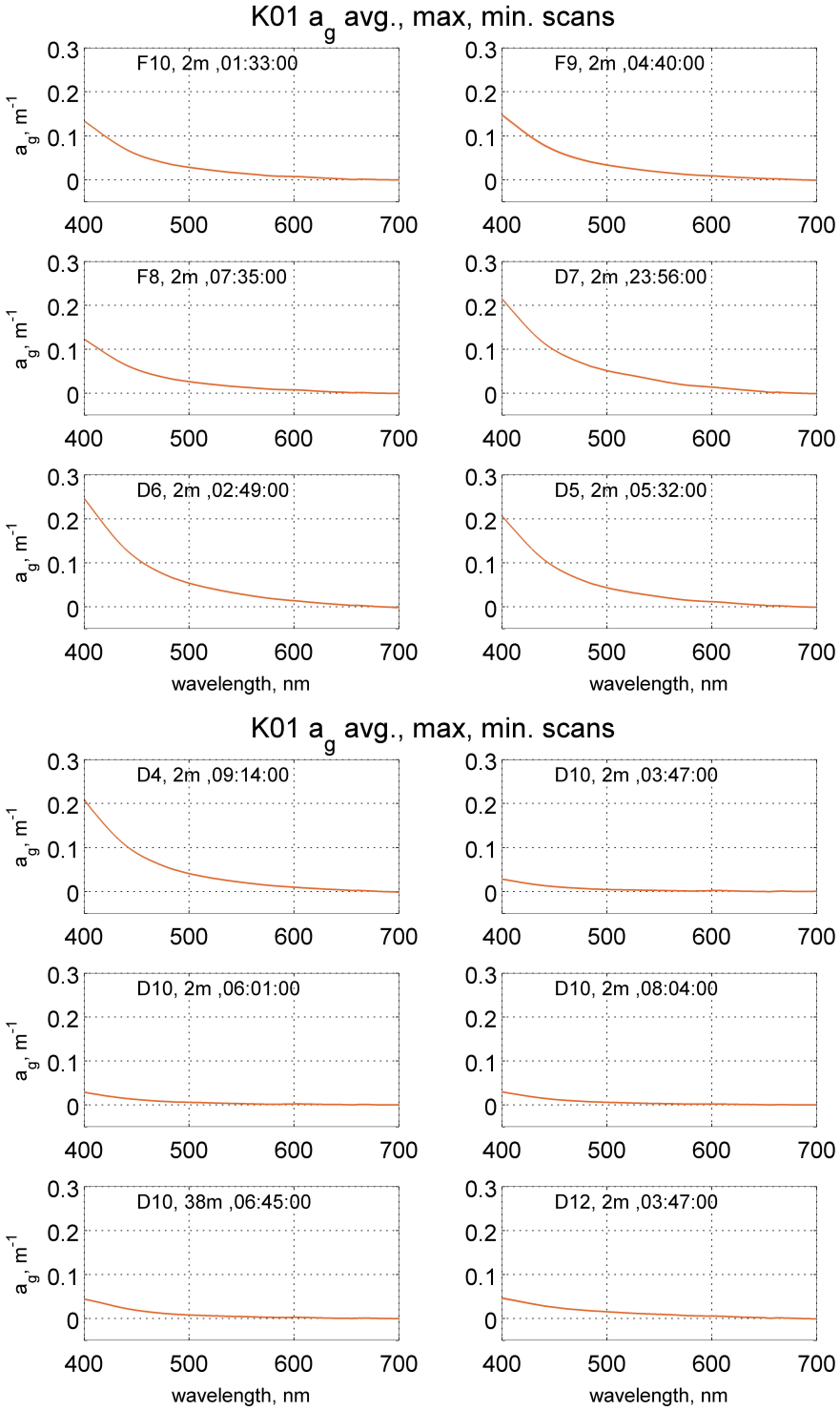

Fig A1. Average CDOM absorption coefficient (a_g) of replicate scans for all samples collected and scanned on board during the 3rd annual GOCI validation campaign ('K01'). Each panel shows the salinity corrected average a_g (orange line) and the max and min envelope for all replicate scans (lighter orange) for each sample.

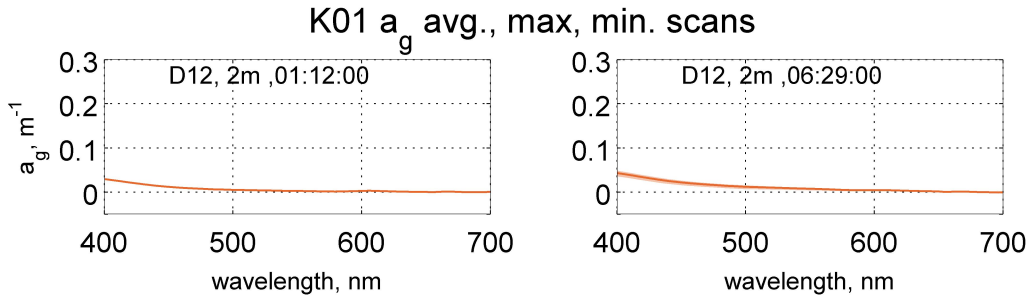

Fig A1 (cont.). Average CDOM absorption coefficient (a_g) of replicate scans for samples collected and scanned on board during the 3rd annual GOCI validation campaign ('K01'). Each panel shows the salinity corrected average a_g (orange line) and the max and min envelope for all replicate scans (lighter orange) for each sample.